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(54) Transmit level control system

(57) A transmit level control system for a transmitter comprises a variable attenuator and means 20, 22, 23 for controlling the variable attenuator in response to variations in the transmitter output power. The variable attenuator comprises a first switched attenuator 15 and a second variable attenuator 17, the response time of the first attenuator to variations in output power being substantially slower than the response time of the second attenuator. The first attenuator provides coarse adjustment to the overall gain of the system whereas the second attenuator provides fine adjustment and deals with short-duration transient conditions. Attenuator 15 may include resistors switched by relays (Fig. 5) and attenuator 17 may be a variable diode attenuator. In a further embodiment (Fig. 6) the switched attenuator 15 responds to preprogrammed decoders controlling the attenuation in a coarse manner appropriate to the frequency data received from a driven unit.

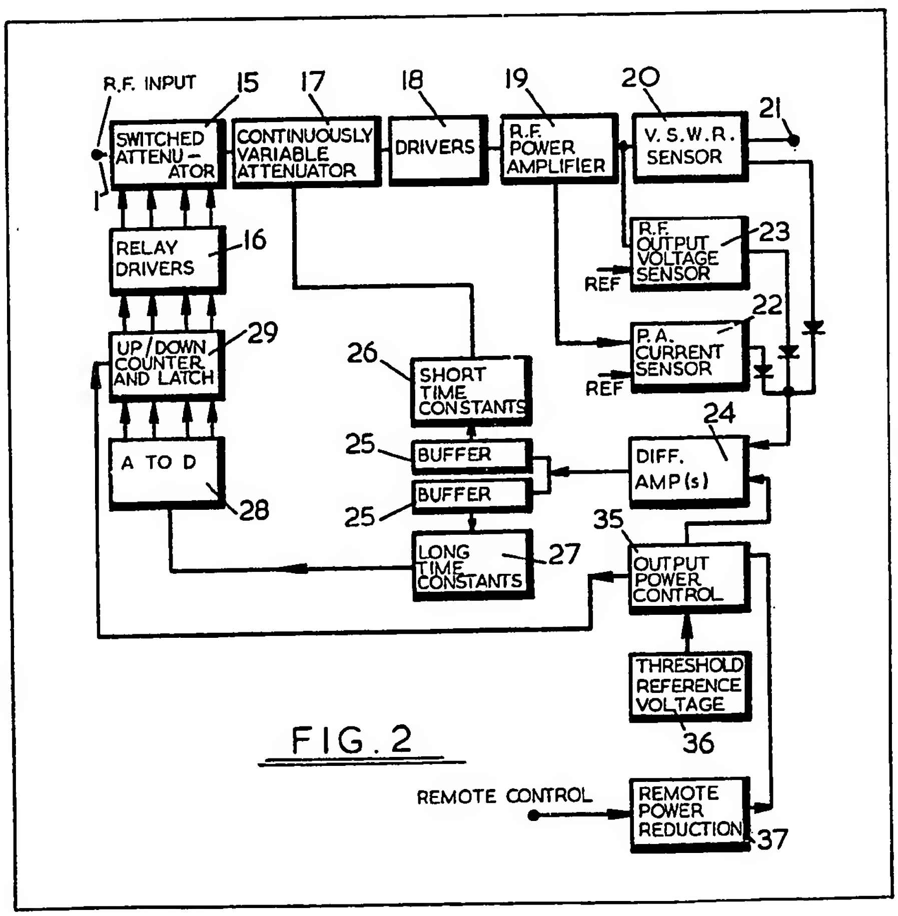

FIG. 2

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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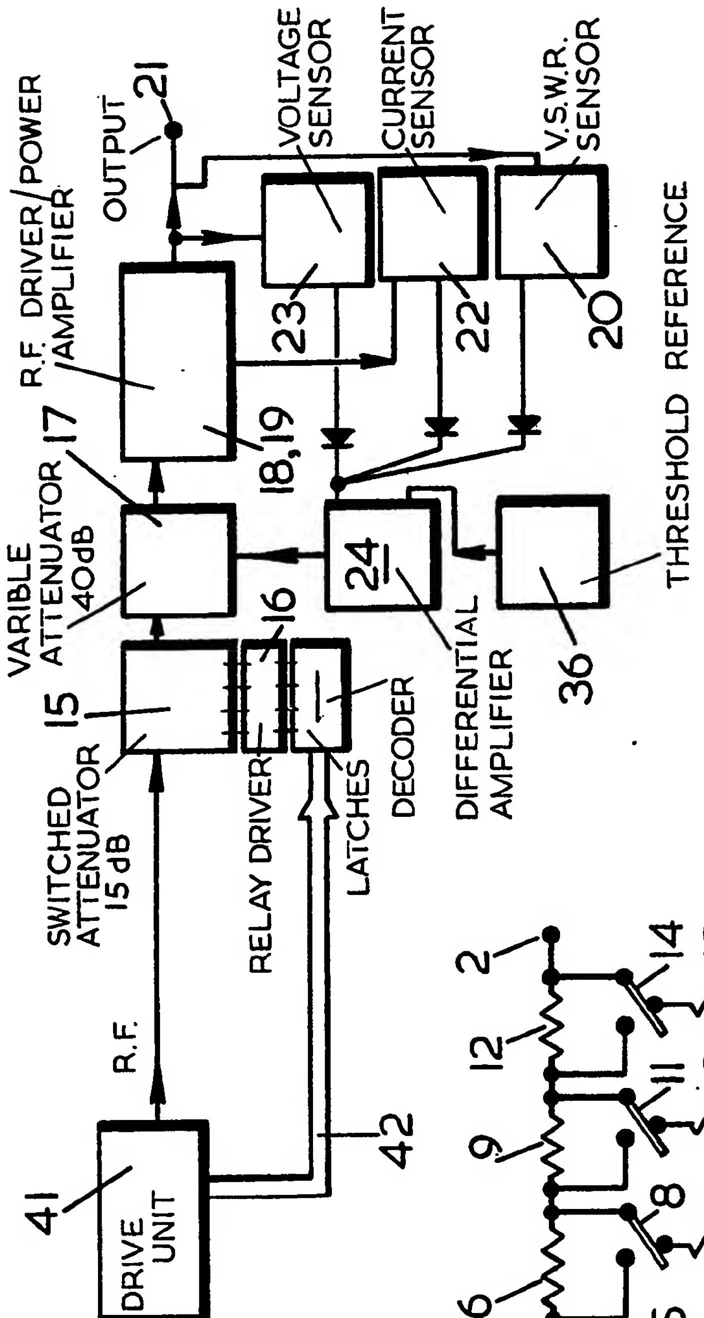
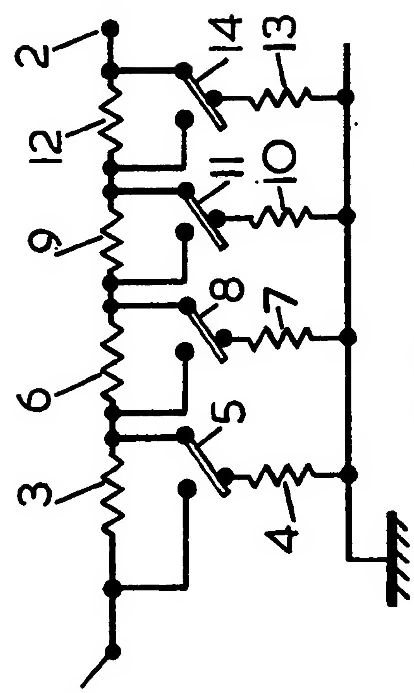


DRIVE UNIT
41
R.F.
42
SWITCHED ATTENUATOR 15dB
15
RELAY DRIVER
16
LATCHES
DECODER
VARIBLE ATTENUATOR 40dB
17
R.F. DRIVER/POWER AMPLIFIER
18,19
OUTPUT
21
VOLTAGE SENSOR
23
CURRENT SENSOR
22
V.S.W.R. SENSOR
20
24
DIFFERENTIAL AMPLIFIER
36
THRESHOLD REFERENCE

FIG. 6



1
2
3
4
5
6
7
8
9
10
11
12
13
14

FIG. 1

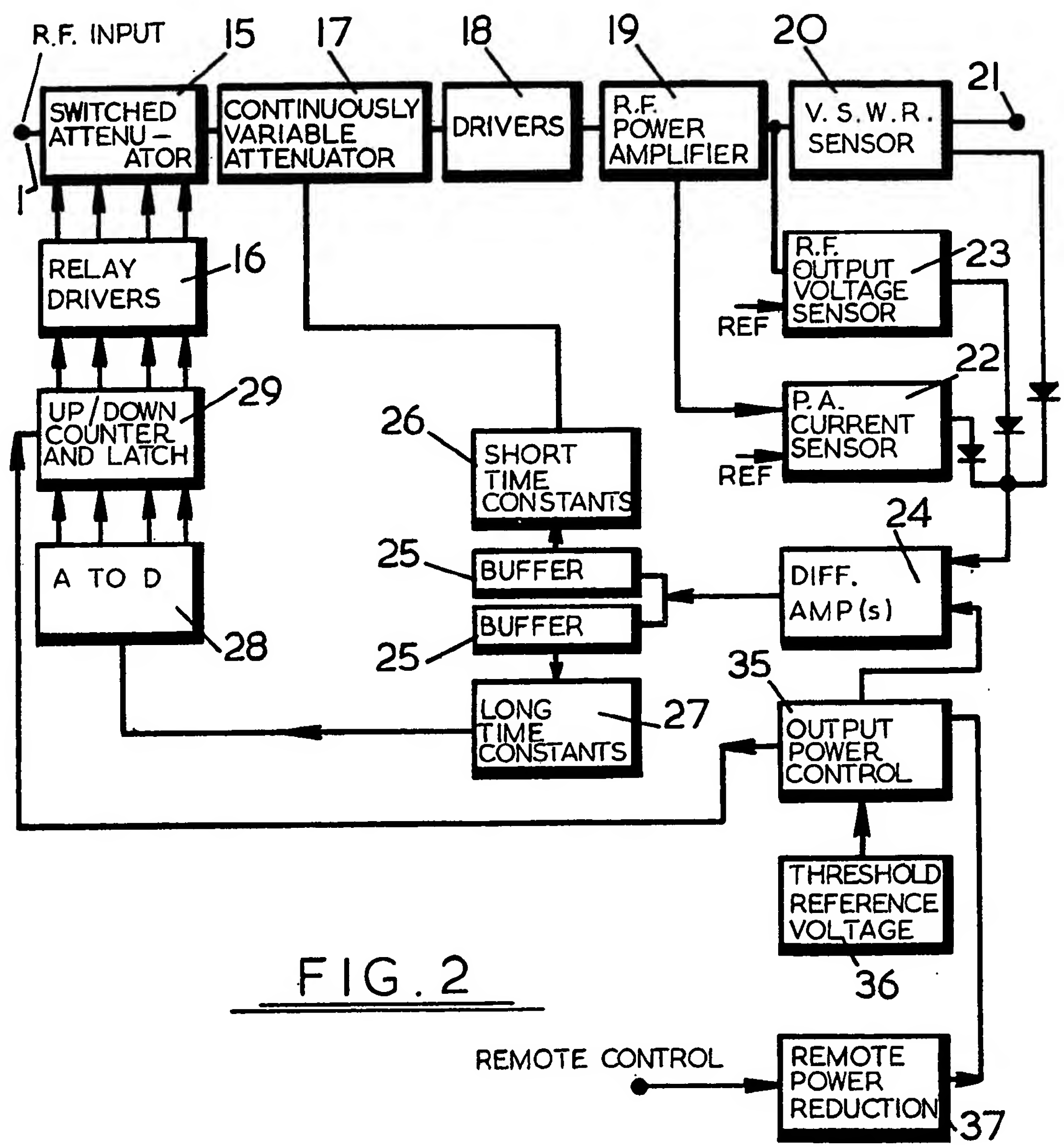

R.F. INPUT
15
17
18
19
20
21
1
SWITCHED ATTENU-ATOR
CONTINUOUSLY VARIABLE ATTENUATOR
DRIVERS
R.F. POWER AMPLIFIER
V. S. W. R. SENSOR
RELAY DRIVERS
16
R.F. OUTPUT VOLTAGE SENSOR
23
REF
29
UP/DOWN COUNTER AND LATCH
26
SHORT TIME CONSTANTS
22
P.A. CURRENT SENSOR
REF
24
25
BUFFER
DIFF. AMP(s)
A TO D
BUFFER
28
25
35
LONG TIME CONSTANTS
27
OUTPUT POWER CONTROL
THRESHOLD REFERENCE VOLTAGE
36
REMOTE CONTROL
REMOTE POWER REDUCTION
37

FIG. 2

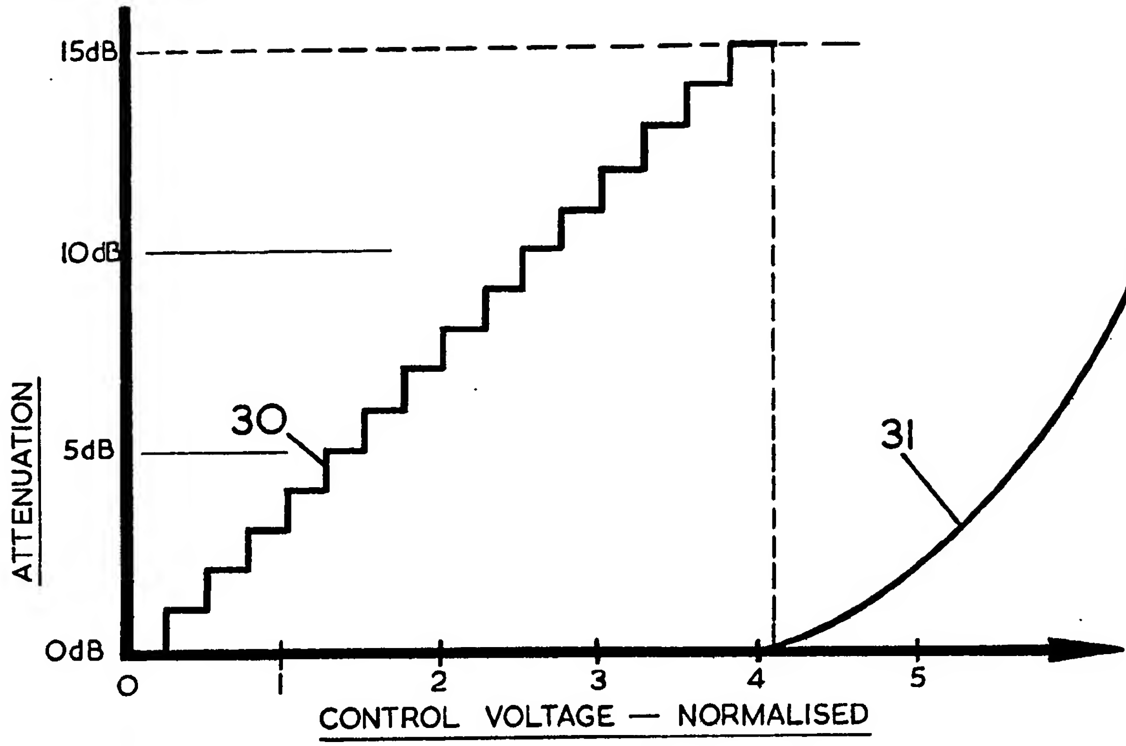

15dB
10dB
5dB
0dB
ATTENUATION
30
31
0
1
2
3
4
5
CONTROL VOLTAGE — NORMALISED

FIG. 3

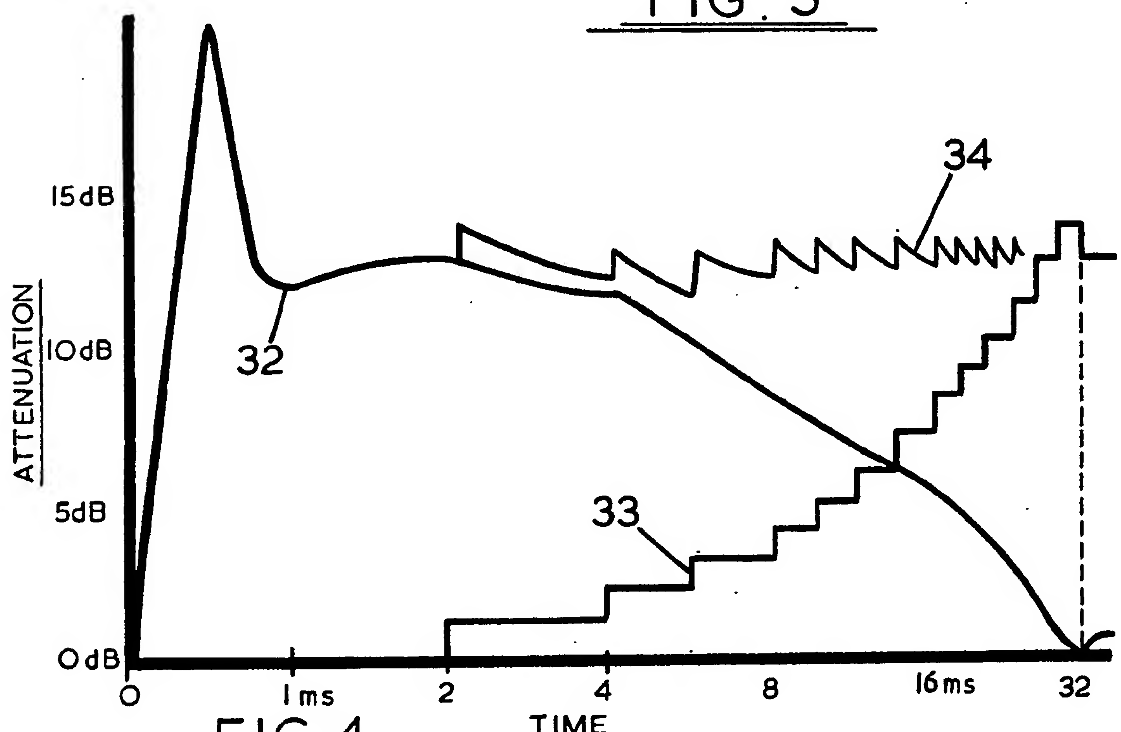

15dB
10dB
5dB
0dB
ATTENUATION
32
33
34
0
1ms
2
4
8
16ms
32
TIME

FIG. 4

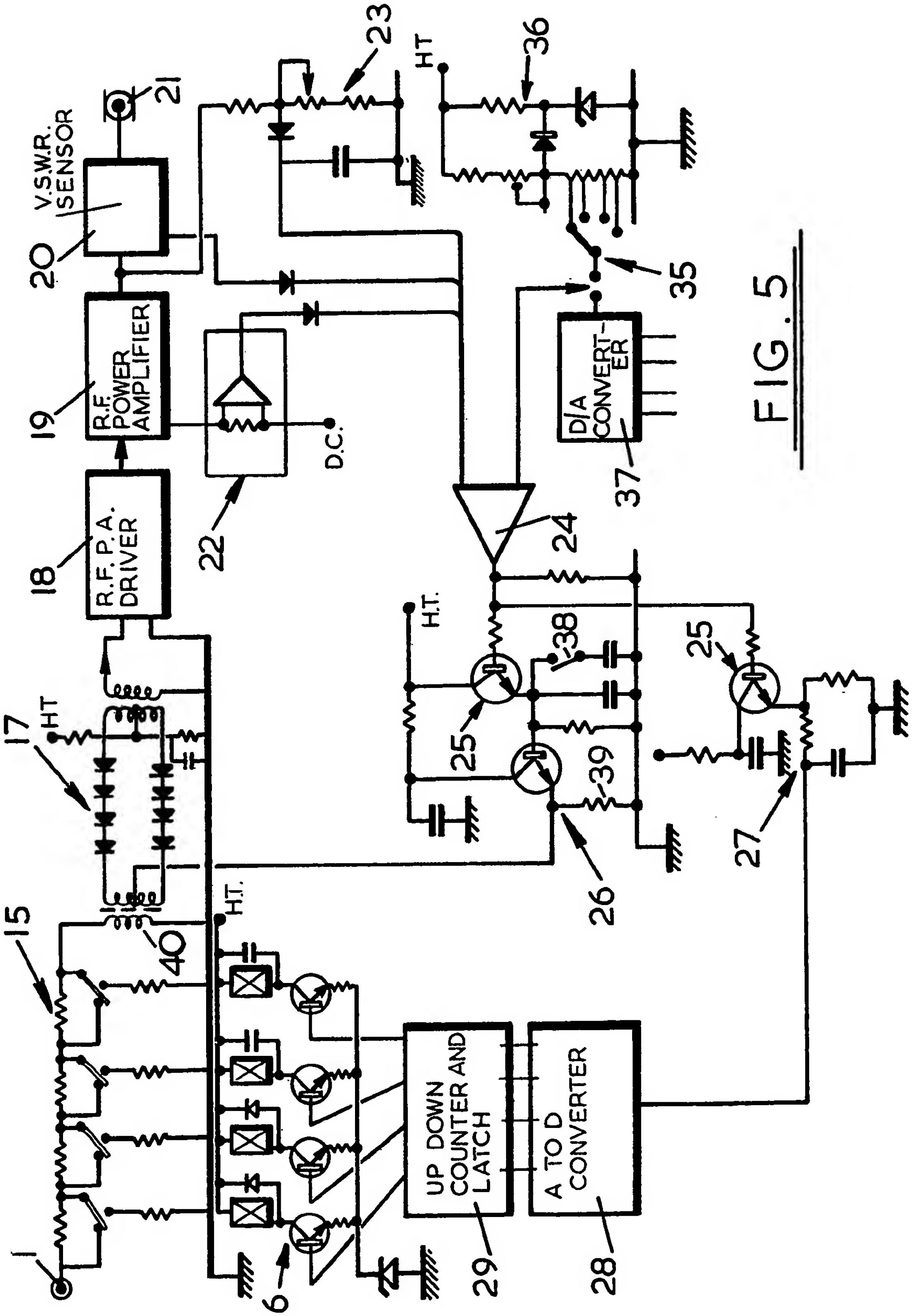

V.SW.R. SENSOR
R.F. POWER AMPLIFIER
R.F. P.A. DRIVER
D.C.
HT
H.T.
D/A CONVERT-ER
UP DOWN COUNTER AND LATCH
A TO D CONVERTER
1
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
35
36
37
38
39
40

FIG. 5

SPECIFICATION

Transmit level control in transmitters

The present invention relates to transmit level control in transmitters.

Transmit level control (TLC) in a transmitter is similar to the function of automatic gain control (AGC) in a receiver in that the transmitter output is kept approximately constant despite overall variations in gain due to frequency variations. This makes it possible to maintain the maximum specified output power with good linearity.

TLC is used to protect the power amplifier transistors of a transmitter from destructive levels of overdrive, and to make it possible for a transmitter to be run in the optimum condition of maximum output power for a specified level of linearity. As an example of what can happen without TLC, a measurement of 3rd order intermodulation products (IP's) taken on a know transmitter at 95 Watts was —30dB. Increasing the output by 1 dB caused the I.P.s to fall to —23dB as a result of overdrive. The overall gain frequency variation of the known system is approximately 6dB. Without automatic TLC the transmitter will either be severely distorting at some frequencies due to overdrive or will have very low output power (e.g. 25 Watts) at some other frequencies.

Known TLC systems exhibit undesirable overshoot, attenuator and attack/decay distortion, unstable level of the side bands on independent side band (ISB) operation, unstable carrier level of double side band (DSB) operation, and noise enhancement.

Attenuator distortion tends to arise because of a continuously variable attentuator operating on the varying characteristic of, say, diodes or field effect transistors tends to have a poor linearity region near its maximum or minimum point of control depending on whether a series or shunt attenuator is used. In this non-linear region the attenuator often worsens the transmitters overall linearity performance.

Attack/decay distortion results from the attack and decay times for TLC which are typically $100\mu S$ and 1 to 5 secs respectively. These time constants impose a low frequency envelope distortion on to the controlled R.F. output.

In ISB operation, assume an operating condition with a TLC attenuation of 6dB when two equal amplitude sideband channels 'A' and 'B' are in use. If channel 'A' closes down or keys off, there will be an instantaneous drop of 6dB in peak envelope power. The TLC then causes the transmitter gain to increase (at the decay — time rate) by 6dB on the remaining channel 'B' during say, 5 seconds. If channel 'A' now comes back on at full power in 1 mS then channel 'B' will be attenuated by 6dB in 1.1 mS. Thus there is an amplitude distortion of channel 'B' caused by channel 'A'.

With DSB operation assume operation with full carrier, 100% modulation depth and working with 6dB of TLC. If the modulation depth drops to 1% then the carrier level will increase by almost 6dB during 5 seconds. A situation similar to that mentioned above with respect to ISB operation results.

It is an object of the present invention to provide an improved TLC system which obviates or mitigates the above problems.

According to the present invention, there is provided a transmit level control system for a transmitter comprising a variable attentuator, and means for controlling the variable attenuator in response to variations in the transmitter output power, characterised in that the variable attenuator comprises a first switched attenuator and a second variable attenuator, the response time of the first attenuator to variations in output power being substantially slower than the response time of the second attenuator.

Thus the first attenuator provides coarse adjustments to the overall gain of the system whereas the second attenuator provides a fine adjustment and deals with short-duration transient conditions.

Preferably the switched first attenuator is in the form of a switched array of resistors which does not produce significant intermoedulation products, switching being effected for example by reed relays. The second attenuator may be a continuously variable attenuator formed from a balanced array of diodes which are heavily biased into the low impedance state.

The resistor array may comprise a series of sections each comprising a series resistor, a shunt resistor, and a switch operative either to short out the series resistor and to disconnect the shunt resistor from the signal line or to remove the short across the series resistor and connect the shunt resistor to the signal line.

The system may operate in a closed loop with predetermined output power, current or voltage standing wave ratio conditions causing a control signal to be applied to the two attenuators via respective timing circuits. Alternatively, the fast-response second attenuator can be responsive to the system output, whereas the slow response switched attenuator is pre-programmed to respond to frequency changes of the system transmitted radio frequency.

Embodiments of the present invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Fig. 1 illustrates a switched attenuator which may be used in systems according to the invention;

Fig. 2 is a schematic diagram of a first embodiment of the invention;

Figs. 3 and 4 illustrate response characteristics of switched and continuously variable attenuators of the system of Fig. 2;

Fig. 5 is a more detailed diagram of the system of Fig. 2; and

Fig. 6 illustrates a second embodiment of the invention.

Referring to Fig. 1, a schematic diagram of a switched step-attenuator such as may be used in

accordance with the present invention will be described. As the attenuator is intended to operate at power levels up to 0.5 Watts it is formed from an array of fixed resistors switched by, for example, reed relays. An RF input signal is applied to terminal 1 and after attenuation appears at output 2. There are four attenuator sections, the first section comprising resistors 3, 4 and switch 5, the second section comprising resistors 6, 7 and switch 8, the third section comprising resistors 9, 10 and switch 11, and the fourth section comprising resistors 12, 13 and switch 14. The switches are shown in the condition in which the attentuation is a maximum at for example 15dB, the first, second, third and fourth attentuator sections contributing 1dB, 2dB, 4dB and 8dB respectively. Attenuation from zero to 15dB in 1dB steps can thus be selected by appropriate actuation of the switches 5, 8, 11 and 14. (It will be appreciated that smaller or larger steps than 1dB may be provided for.) The illustrated arrangement provides that the input and output impedances are constant.

The switches are arranged such that when one of the switches (e.g. switch 5) operates to remove a short circuit across one of the series resistors (e.g. resistor 3) there is a delay before connection is made with the associated shunt resistor (e.g. resistor 4). This results in the attenuation being increased in two steps so that the attenuation effect is smoothed and transients are reduced.

The use of a binary switching sequence can cause the generation undesirable transients because of progressive variation of attenuation in 1dB steps can require the operation of all switches during a 1dB step and if their open/close sequence is not perfectly synchronised there will be transients of intermediate attenuation. These effects can be reduced by using as an attenuator a simple ladder attenuator with fifteen 1dB attenuator sections controlled by fifteen switches rather than the fifteen sep "binary" attenuator illustrated.

The attenuator may be arranged in a fail-safe mode, i.e. if the control connections to the switches go open or short circuit the attenuator will switch to maximum attenuation.

Referring now to Fig. 2, a schematic diagram of an embodiment of the invention will be described. A switched attenuator 15 of the type described with reference to Fig. 1 is connected to the R.F. input 1, the switches of the attenuator being controlled by relay driver circuit 16. The output of the switched attenuator 15 is applied via a variable attenuator 17 to R.F. power amplifier drivers 18 which drive the R.F. power amplifier 19. The R.F. output is passed via voltage standing wave ratio sensor 20 to an output 21.

The continuously variable attenuator 17 is only normally in use over a large attenuation range for the initial few milliseconds when setting up the level of a newly initiated channel. It does not need to meet the same high linearity standards required of the stepped attenuator which is in use throughout the operational phase. For example the continuously variable attenuator may be such that it is highly linear in its "Off" condition and up to its first 1dB of attenuation.

As shown in Fig. 2, the switched attenuator 15 is sited at the input of the R.F. power amplifier. The attenuator 15 has 1dB steps selectable by the relay drivers 16 so that the attenuator will run up or down with approximately 1—2mS between each 1dB step. The attenuator 15 provides very good linearity, i.e. better than —80dB intermodulation products (based on a standard two tone test). The output of the R.F. amplifier 19 is monitored by current and voltage sensors 22, 23 which derive sense voltages from the R.F. output and compare it with voltage and current threshold references (24) so that a control voltage is obtained when either sense voltage exceeds these thresholds. The reference which is used to set up the thresholds is taken from the HT line and stabilised against positive excursions so that, if the HT increases, the threshold remains the same. If the HT decreases, then the output from the regulator also decreases so that the threshold decreases. Thus we have a means of keeping power constant with increasing HT but of reducing power when the HT decreases. This ensures that the optimum transmitter output power is achieved despite variations in the mains supply. The outputs from sensors 22 and 23 are fed to a differential amplifier 24 the output of which is fed into buffer stages 25. The differential amplifier 24 also receives the output of the V.S.W.R. sensor 20 which gives a control output when the V.S.W.R. exceeds for example 3:1.

The output control voltage from one buffer 25 is fed to the continuously variable attenuator 17 via short time-constant circuit 26 and the output from the other buffer 25 is fed to the stepped resistor attenuator 15 via long time-constant circuit 27, analogue-to-digital converter 28, up-down counter and latch 29, and relay drivers 16. The buffer output 25 to the continuously variable attenuator 17 is arranged so that a rising control voltage at the buffer input results in the current supplied to the attenuator decreasing. This reduction in current causes series attenuation to be produced by attenuator 17. The other buffer 25 produces a slow rise of the control voltage such that its effective output operational range is covered in approximately 30mS. This voltage is fed into the 4 bit A—D converter 28. The output from this is fed through counter/latch 29 to the relay driver which, the switches the attenuator 15.

Fig. 3 shows the attenuation versus control voltage function (at the input to buffer 25 of Fig. 2) for the two attentuators 15 and 17. If will be seen that the switched attenuator (curve 30) operates at the lower end of the voltage control range compared with continuously variable attentuator (curve 31).

Fig. 4 shows the response of the attenuators with respect to time. The continuously variable attenuator is very fast in its action (curve 32) in as much as it covers its full range of attenuation in from 100 to 500 μS. It has a fast decay, this being

limited in speed by the need for the transmit level control not to follow A.F. envelop waveforms. It would be advantageous to have a decay as fast as 4mS to allow ganged opertion of both attenuators, but this would not be compatible with A.F. modulation. The switched stepped attenuator is by comparison slow in its action (curve 32). It does not achieve its first 1dB attentuation step until after approximately 2mS, with successive attenuation steps of the same time order, so that it may take up to 30mS to cover its complete range. curve 34 shows the combined attenuation. The graphically illustrated example corresponds to the case of a combined attenuation control of 12dB.

Thus Fig. 4 shows how a complete range of TLC attenuation is achieved as a function of time. It will be seen that the less linear continuously variable attenuator acts very rapidly to bring control to the circuit. Because of its low gain and relatively fast decay time there is only a small overshoot effect within the first 2mS. After approximately 2mS when attenuator 17 has reached a steady state the fixed attenuator starts to operate, and because of its greater sensitivity to the control voltage it dominates over the continuously variable attentuator whose attentuation decreases as the switched attenuator's increases. The combined attenuation (curve 34) remains approximately constant. After some 30mS only the switched attenuator remains operating. It should be noted that when this has happened the continuously variable attenuator is either in the high-current low-impedance mode, or operating with less than 1dB of attenuation. Thus the continuously variable attenuator, although still available for any rapid corrective action in terms of increased attenuation in the system, is otherwise in its relatively linear or non-operating condition.

A 'tune disable' input (not shown) should be provided to the A-D converter 28 so that the converter may be put into the minimum voltage condition, i.e. minimum attenuation. This is so that the switched attenuator does not function during a tune period where the output (21) can be terminated by a load which will go from a high impedance to a matched condition. Attenuator 15 should not be operational during this tuning period. Thus during the tune mode the continuously variable attenuator is operating and the lack of linearity due to this is of no concern as this is not an operational condition.

When the switched attentuator 15 is in operation, there is bound to be a condition wherein the attenuation is being stepped in, until the end of the required control is just being reached. Say it is required that the output power is needed to be established by TLC at 1kWatt, and assume that sufficient steps of attenuation have been activated to reduce the output to 1kWatt plus 0.2dB. The system will decide that more attenuation is needed and the next step of attenuator 15 will be further 1dB reduction. The output will then be 1kWatt minus 0.8dB. It is necessary/to prevent finally latching the attenuator in this condition of low power. To deal with this, the up/down counter and latch 29 has a latched mode and a transparent unlatched mode. In the "unlatched" condition the output of converter 28 goes straight through to activate the attenuator relay drivers. When the system has stabilised the gain (1kWatt minues 0.8dB in the example), the output to the relay drivers is latched and the latching signal then causes a "count down 1dB" action, i.e. the counter goes down by one binary number and the switched attenuator releases 1dB of attentuation. The output power is then 1kWatt plus 0.2dB. The continuously variable attenuator 17 now takes control and provides 0.2dB attenuation so that output becomes the recquired 1kWatt. The attenuator 17 now provides 0.12dB of attenuation which may be reduced to 0dB in order to compensate for losses in overall gain. This process of "latch-and-step-back-1dB" ensures that the system does not end up with too much switched attenuation in circuit and allows a little continuous control to be kept in hand to look after small decreases of gain in the overall transmitter system.

An output power control circuit 35 supplies the reference voltage to the differential amplifier 24. If the reference voltage supplied by threshold circuit 36 is halved, then the R.F. output voltage and current swings will be halved and the power will decrease by 6dB. The benefits of the level control system will still apply at this reduced power level. The reference voltage level may be remotely controlled by means of a D to A converter 37 if desired or by some other means.

Fig. 5 shows further circuit details of the system illustrated in Fig. 2, the same reference numerals being used in the two figures. Those components not shown in detail are essentially conventional and accordingly will not be further described.

Referring particularly to Fig. 5, the response of the system to an overdrive will be described, as an illustration of the system. Assume than an overdrive of 13dB has been applied at terminal 1 for a period of 500 μS. This causes the continuously variable diode attenuator 17 to take control and when the system stabilises the output R.F. power is 1kWatt plus 0.13dB. The R.F. output voltage sensor 23 is a peak voltage rectifier which gives say 5 volts D.C. as drive to the operational amplifier 24 with exactly 1kWatt R.F. output. When the threshold reference to the amplifier 24 is 5 volts there will be no control voltage but with an R.F. power increase of 0.13dB the amplifier 24 has an input of 5.075V or a differential of 0.075V. The differential amplifier 24 has an emitter follower output and feedback is used to give 40dB gain so that an output of 7.5V D.C. is obtained. This is applied to the buffer 25 and amplifier 26 with the short time constant. The output at 26 increases to 6V and this biases the diode attenuator such as to cause it to attenuate by 13dB. The correction factor is therefore 0.13dB charge in output for a variation of 13dB in input. The buffer with the long time constant (charge time approximately 22mS) will not have produced

sufficient output to increment the D/A converter 28 so that the switched attenuator 15 is at zero attenuation. Without control voltage applied to the buffer 25, controlling the continuously variable diode attenuator 17 the emitter resistor 39 limits the diode attenuator current to a maximum of about 90m/A. This is the minimum attenuation condition.

The diode attenuator 17 has two diode chains and an input circuit comprising transformer 40. The transformer secondary may be split to ensure that the two diode chains have well defined equal currents. It was may also have a balancing control to null the control voltage transient.

When a transmitter incorporating the described system is to be tuned, an automatic tune sequence is started and the A/D input is disabled as mentioned above so that the stepped attenuator 15 is set to zero. The power reduction switch may also be set to low power if this is required by the desired tuning sequence. As a result of starting the tune sequence, an audio test tone is fed to the system input. The resultant R.F. level will be more than is needed for the desired output R.F. power. Therefore the voltage and/or current sensors 22, 23 will provide an output greater than the threshold reference voltage. This will cause the differential amplifier 24 to provide an output which operates the continuously (fast-acting) variable attentuator 17 which reduces the R.F. drive to ensure that the P.A. current and voltage are not above the correct level. As tuning takes place the correct load will gradually be presented to the P.A. and in the process the continuously variable attenuator 17 will be required to adjust for the resulting gain variations. When tuning is complete, the power reduction switch is returned to the full power condition and the "disable" is taken off the A/D converter 28. This allows the control voltage to be applied to the input of the A/D converter and the resultant 4 bit output will pass through the up/down counter 29 (which is still unlatched) and operate the relay driver 16 which will operate the relay driver 16 which will operate the switched attenuator 15. While this is happening the continuously variable attenuator 17 will reduce toward zero attenuation by the time the switched attenuator 15 is fully set. The up/down counter 29 now latches and the output reduces its count by one, causing a 1dB relaxation of the switched attenuator. This then brings the continuously variable attenuator 17 into action as a fine active control. In parallel with the latching of the switched attenuator 15 there occurs an insertion of extra capacitance (by operation of switch 38, Fig. 5) in the time constant circuit of the control line to the continuously variable attenuator 17. This now means that the 0 to 1dB of fine control has a longer time constant in order to minimise envelope distortion of the radio frequency output at 21.

If during the operating conditions the power reduction control 35 is operated it will also cause the up/down counter to count down or up a digital number equivalent to the power increase or decrease as measured in dB's, thus setting the drive to the level needed for the new output power level. The necessary connection between control 35 and counter/latch 29 is shown in Fig. 2, but not in Fig. 5 to avoid over-complication of that figure.

As an alternative to the closed loop control system of Figs. 2 and 5, a preprogrammed system may be provided. Such a system is illustrated schematically in Fig. 6, the reference numerals common to Figs. 2 and 6 identifying equivalent components.

In the system of Fig. 6, a drive unit 41 is shown which provides the R.F. input to the switched attenuator 15. The drive unit may incorporate a postselector (not shown) to improve frequency selectivity. The drive unit provides operating frequency identifying outputs on data channel 42 which is connected to decoder/latch 43. The decoder/latch controls the relay driver 16.

The decoders are preprogrammed to respond to the frequency data received from the drive unit 41 so as to affect control of the switched attenuator 15 appropriate to that data. Thus, the switched attenuator 15 provides coarse attenuation control, minor output power variations being taken up by the continuously variable attenuator 17 which is controlled via differential amplifier 24 and sensors 20, 22 and 23 in exactly the same way as in the case of the attenuator 17 of Fig. 2.

The gain/frequency characteristics of transmitter drive units is complex and accordingly a complex programme is required. In addition gain spreads in production make it advisable individually to programme discrete systems. Ageing or gain variations due to maintanence might require adjustments to the programme. It is however not necessary to override the system during tuning.

It will be appreciated that the specific embodiments of the invention described herein are given merely by way of example and that alternative response times and attenuation levels may be selected as desired.

CLAIMS

1. A transmit level control system for a transmitter comprising a variable attenuator, and means for controlling the variable attenuator in response to variations in the transmitter output power, characterised in that the variable attenuator comprises a first switched attenuator and a second variable attenuator, the response time of the first attenuator to variations in output power being substantially slower than the response time of the second attenuator.

2. A control system according to claim 1, wherein the switched first attenuator is in the form of a switched array of resistors.

3. A control system according to claim 2, wherein switching of the array of resistors is effected by reed relays.

4. A control system according to any preceding claim, wherein the second attenuator comprises a continuously variable attenuator formed from a

balanced array of diodes which are heavily biased into the low impedance state.

5. A control system according to claim 2 or 3, wherein the resistor array comprises a series of sections each comprising a series resistor, a shunt resistor, and a switch operative either to short out the series resistor and to disconnect the shunt resistor from the signal line or to remove the short across the series resistor and connect the shunt resistor to the signal line.

6. A control system according to any preceding claim, wherein a system operating condition is sensed and a control signal dependent upon the sensed condition is applied to the two attenuators via respective timing circuits.

7. A control system according to any one of claims 1 to 5, wherein the fast-response second attenuator is responsive to the system output and the slow response switched attenuator is preprogrammed to respond to frequency changes of the system transmitted radio frequency.

8. A transmit level control system substantially as hereinbefore described with reference to the accompanying drawings.

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